"Fine-Dusty": Gamification of Particulate Matter Risk Communication

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Abstract

With the increasing severity of particulate matter problems, the current media have begun to deal with this issue. Yet awareness of the problem is still very low among many people. In this study, we applied gamification methods to risk information communication to overcome the limitations of information from the previous particulate matter media. Via a design science research methodology and design process of the gamification, user needs regarding risk communication were defined and gamification was identified as a promising design alternative. Attributes of information design extracted from user research were implemented to guide the game elements. Effectiveness of the gamified application was evaluated through presurvey and postsurvey using remote unmoderated user testing. Based on self-determination theory, the relationship between game elements and required information design aspects, the effect of game elements on user motivation was evaluated. As a result, the effect of using the particulate matter game application was verified to bring affordance and internal and external motivation to users. In the case of internal motivation, autonomy was affected but competence and relatedness were not. Furthermore, the gamification application influenced users' reduction action, knowledge of the problem, and empowerment regarding particulate matter after using the prototype.

1. Introduction

Environmental problems are addressed globally as chronic problems, especially because air pollution affects chronic diseases [41]. In recent years, the problem of air pollution has gained much attention in Korea. The World Health Organization defines dust particles of less than 2.5 μg as ultraparticulate matter. Particulate matter refers to fine particles and droplets of various components such as nitrate and sulfate, organic chemicals, metals, and soil and dust [21]. Prolonged exposure to low concentrations of particulate matter has been shown to reduce pulmonary function in asthmatic patients and children, increase respiratory stress, and aggravate cardiovascular disease, leading to increased disease and death. Thus, exposure to particulate matter is closely related to increased disease rates and mortality [2].

As the magnitude of the particulate matter problem has increased, the national government has responded to the problem but failed to provide a fundamental solution to industrial, diplomatic, and environmental problems. Despite the severity of the problem, the population's knowledge of the causes, risks, and methods of response remains low, and modes of communication about particulate matter information is largely responsible for this problem [23]. By locating the cause of the particulate matter problem from the outside, the incongruity that shifts the solution to individuals reduces the self-efficiency of individuals' control of particulate matter and increasingly reduces the will to respond to the problem [41]. Also, the information delivery method regarding particulate matter, which is complex, enhances the psychological phenomenon. At a time when understanding is lacking regarding the dangers of particulate matter due to the inconsistent and complex nature of the information, the risks of particulate matter cannot be easily shared by conveying information such as particulate matter levels and danger alerts.

In this study, risk communication was explored via a novel solution using gamification attributes.

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Gamification, "the use of game design elements in a context other than a game" [5], has the advantage of designing a virtual world based on reality for a specific purpose, to prompt a particular action [7,30]. Furthermore, we tried to improve the particulate matter information transmission method by applying concept frames of self-determination theory [36]. For this purpose, we followed a design science research methodology [14,28] and design process of the gamification [34] in the overall research, which starts with analysis and progresses into evaluation. At the analysis stage, information design attributes were extracted based on user characteristics and context of risk communication. In the ideation stage, the information design attributes regarding risk communication were applied to game elements. In the design phase, we implemented a prototype of particulate matter based on possible graphical concepts and gamification elements derived from the ideation phase. In the evaluation stage, information design attributes, game elements, and the effect of application were evaluated to examine whether game elements properly addressed the information design needs of the users and affordance. In conclusion, the "Fine-Dusty" game came out to bring affordance and generated internal and external motivation to users. In terms of risk communication, our gamification application influenced users' reduction action, knowledge of the problem, and empowerment regarding the particulate matter problem after using the prototype.

2. Related work

2.1. Risk communication about particulate matter

The amount of information affects the systematic level understanding of risk-related information, so a large amount of information is required to prompt a response behavior [18]. As the severity of the particulate matter problem increases, information about particulate matter flows through news, the internet, public service advertisements, warning messages, and the like. However, the amount of information accepted by individuals is minimal, indicating the problem of risk communication methods regarding particulate matter. With particulate matter being reported at an unavoidable high level of risk in Korea, opinions on particulate matter are forming among individuals based on media framing [15].

According to existing risk communication studies, the method of conveying particulate matter information, such as complexity, expertise, consistency, intuition, certainty, and personalization are closely related to information acquisition [24]. The poor communication method of current media prevents the public from clearly grasping the organic relationship of each element, even though they have expert knowledge about the concept, cause, health effect, and solution regarding particulate matter. Also, reliable information transmission is an important factor to consider as an information delivery method [25]. Furthermore, According to Li et al. [29], information can be accepted psychologically if it is close to personalized information to effectively communicate about a response behavior [1]. According to Kim et al. [20], an individual's level of knowledge directly influences intent to reduce or avoid a dust source on an individual level. In addition to anxiety, the factor of psychological distance is correlated with the motivation of the individual, and information about the dangers of particulate matter and the resulting response behavior also differed according to psychological distance. Finally, individuals at a psychological distance showed more disagreement between perception and action [23].

In spite of the popular use of particulate matter-related application services, the limits of access to information provision, information expression, and personal dimensions still make it difficult to acquire and respond to particulate matter information. Therefore, in this study, we explored the characteristics of information delivery and information expression that is required by users and designed gamification elements based on them.

2.2. Gamification

The most widely used definition of gamification in recent years is "use of game design elements in a context other than a game" [5]. This term generally refers to the process of designing and using games for a specific intent or purpose. However, in a narrow sense, it refers to a game in which a simple action-inducing concept such as a point, badge, quest, or leaderboard, used for motivation [30,32]. In sum, gamification means a service and system design process that enhances services with affordance for a game-like experience that affects user behavior [16].

2.2.1. Gamification and affordance. According to self-determination theory [36], The affordances are an important context in gamification, because game system elements appear to require the user to voluntarily rather than automatically interact with the system [17,44]. The affordances form the game system and lead to behavioral outcomes that increase psychological outcomes and physical activities such as competence, autonomy, relatedness, and engagement. The elements of the game related to behavioral outcomes include points, leaderboards, achievements, levels, stories and

themes, goals, feedback, rewards, progress, and challenges. To the extent possible, they address the specific psychological needs of the user [12]. Research on the psychological outcome of gamification focuses mainly on motivation, user behavior, and pleasure factors [12].

2.2.2. Gamification and motivation. From a motivational point of view, research has been conducted on system design to satisfy external motivations related to utilitarian systems [3,40] and hedonic internal motivations. External motivation focuses on productive system means and design, intending to efficiently increase the usefulness of the system. Intrinsic motivation aims to increase the cognitive, emotional, and social benefits to create a playful experience centered on the entertainment factor. In particular, internal motivations such as competence, autonomy, and relatedness were found to be related to immersion, achievement, and social gamification feature[43]. A game's story evokes the meaning and voluntary involvement of one's actions [35,37], and game rules and characters also promote immersion by allowing users to experience the game. Points, levels, badges, and leaderboards that generate behavioral incentives help improve a user's skills by encouraging specific actions [10]. Leaderboards can also be used to represent competitive indicators of activity performance [37]. Through the competence factor, users form relationships with other users, and the connection and belonging generated through them satisfy relatedness [4].

2.2.3. Elements of gamification. Narratives and stories can provide immersion facilitation and strengthen immersion mediation of autonomy and immersion satisfaction. And generally, avatars are visual representations of players in the game or gamification environment [42]. Usually they are chosen or even created by the player [19]. Customization is defined as "an activity that modifies some aspects of the interface to some degree to make the user personally relevant" [33]. Badges are used to reward users for favorable predefined behaviors [26]. Therefore, in this study, we designed the elements to induce motivations and also deliver particulate dust information.

3. Our approach

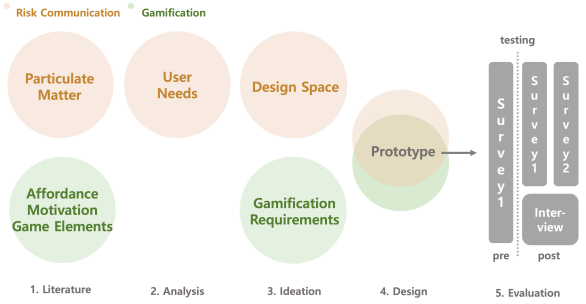

Figure 1. Gamification design process of risk communication

This study approached risk communication through gamification. It was based on the design science research methodology [14,28] and developed through the design process of gamification [34] which follows analysis, Ideation, Design, Evaluation. The overall process of the study is shown in Figure 1. First of all, through a literature review, the problem of information acceptance in risk communication and the theoretical background of gamification, which is self-determination theory [36] was confirmed. In the Analysis phase, the user's needs and context were analyzed based on the implications in the particulate matter risk communication literature. In the identification phase, application ideas were expanded by comprehensively considering the design space and the gamification theory. In the design phase, the final design was determined at the point where the theory of screening and the risk communication design space converge. In the last stage, Evaluation, remote unmodified user testing was carried out realistically based on days when the particulate matter was high. At the same time, the effects of application use on fine dust communication were assessed through pre- and post-survey survey comparison. In the post-survey and interviews, the information design attributes and factors to accommodate particulate matter apps applied to games were evaluated.

4. Analysis

At the analysis stage, we sought a profound understanding of users and contexts. We analyzed the definition and characterization of the target group, as well as the identification and understanding of contextual characteristics of "Fine-Dusty" [6,13]. The interview involved semistructured interviews with 12 participants (two male and 10 female) in their 20s and 30s for around 1 hour. It was structured to identify users'

attitudes and perceptions of particulate matter issues, understanding and knowledge of the problem, and actions taken regarding the issue. Specific interview questions focused on information-searching patterns, action toward the issue, patterns of application usage, and other related topics.

4.1. User characteristics

Interviews were analyzed using axial and selective coding. The interview results were composed of the aforementioned categories. The upper criteria were divided into four categories: behavioral response, information acceptance, attitudes toward response, and problem recognition levels. Each category was reclassified into subcriterion. Five personas were derived based on the combination of each subcriterion.

Response behavior pattern refers to mask purchase patterns, strictness in mask purchases, and active response action. Information acceptance means the sensitivity of information acceptance. Level of need for information refers to the degree of avoidance of information. Response attitude means willingness to respond and knowledge level. Level of problem recognition means anxiety, damage level, effects of a social network, and cause of particulate matter.

4.2. Persona

Personas were derived according to the status and degree of behavioral response, information acceptance, attitudes toward response, and problem recognition levels. There are three reasons for focusing on the latter three personas. First, these groups had the lowest level of knowledge about and response to the particulate matter problem. Accordingly, these persona groups most urgently needed knowledge and responses regarding particulate matter. The second reason is these personas indicated a high level of inconvenience in taking actions to address particulate matter issues and thus, had a low level of willingness to respond and prevent issues. Unlike groups that voluntarily and preemptively prepare for particulate matter, even without friendly and intuitive services, these personas have a high level of resistance to scientific terms and complex information regarding the particulate matter problem. As a result, these groups need information provided in a different way than the existing particulate matter services to promote their willingness to respond.

5. Ideation

In the ideation stage, we developed a gamification design through iterative brainstorming activity [7,13] to understand possible design alternatives, or "design space" [11]. We also followed the typical user-centered design framework [31]. System, service, information, situation, and other elements being designed were extracted from the needs of the user. The visual design and GUI elements were borrowed from *Cats are Cute* (kkiruk studio, 2018) [45]. Primary data and secondary sources were collected and interpreted in the form of design criteria [38]. Four main phases [8] were applied in the ideation process.

5.1. Design Space

Table 1. Design space and subcategories

Design Space	Subcategory
Information design attribute	Implications, specific, intuitive, personalization, emotional, persistence, preemptive, accessibility, ripple effect, interaction
Type of information	Status of particulate matter, how to respond, extent of damage, professional and objective information
Situation	Before going out, after going out, staying indoors, staying outdoors
Function	Push notification, user interface, Chatbot, SNS sharing, information for today, yesterday, and tomorrow, geographic information, simulation games
Applicable interfaces	Voice, chatbot, visual

According to the results of the interview analysis, there are five main design spaces. Design spaces consisted of information design attributes, functions, interface types, information types, and situations. First, information types refer to the type of information provided to the user. Next, Different information was required depending on the different situations facing users. Information delivery methods that can be efficiently communicated to users were defined as and classified into 10 categories. Third, Situation and functions were divided based on the contet users require about the particulate matter information Finally, applicable interfaces were listed based on the feasible interfaces based on the current service research. Details of subcategories are listed in Table1.

5.2. Design rationale

The following reasons indicate why we adopted certain gamification elements for particulate matter risk communication. Rationale of the gamification elements was based on information design attributes, which were an essential part of the design space. The hypothesized strengths of this service are summarized in Table 2.

Table 2. Implemented design and information attributes

Elements	Design	Information attribute
(a)Narrative /Story	Daily Life of the Avatar	Specific Persistence Preemptive
(b)Tasks	Prevention of the Particulate Matter	Specific Persistence Preemptive Interaction
(c)Avatars	A White Puppy	Intuitive Emotional Interaction
(d)Character/Customiz-ation	Avatar Outfit, Furniture items	Personalization Implication Prevention
(e)Customization/Per-sonalization	GPS based scenario	Personalization Interaction Intuitive Preemptiveness
(f)Points /Levels	Leaf and Mask items	

First, we attempted to provide information using sensitivity and an intuitive interface the game. An avatar was assumed to have potential for this task. Because a lack of empathy and formal information were mentioned as limitations of previous services in interviews, a simulated game character was expected to be an alternative. Furthermore, avatars promote immersion by allowing users to experience the game [10]. Second, we tried to deliver information and responses to the particulate matter problem based on current status, and a task was considered as an appropriate alternative. Tasks could not only allow users to express information about particulate matter in a roundabout way but also may provide information in an interactive and intuitive way because they are graphical and emotional. Thus, it was hypothesized to raise awareness of particulate matter and induce actions in the case of personas who are relatively less conscious about particulate matter. Also, game rules were expected to promote immersion by allowing users to experience the game [10]. Third, we attempted to maximize emotional communication and help users feel integrated with their characters. We expected the narrative or story of the game to be a possible alternative, especially with GPS-based monitoring. The narrative or story was based on the scenario that the avatar follows the user during the day and the status of the world and condition of the character (whether dirty or clean) reflects the status of the user.
This narrative was expected to also generate tasks that enhance persistence. Also, a game story evokes the meaning and voluntary involvement of one's actions [35]. Fourth, we assumed that providing contextual and timely information when going outside or returning home based on GPS could enable personalization and preemptiveness. Also, it is possible to provide detailed information on the current situation through a function that shows the current status of exposure to particulate matter based on the user's daily path. Fifth, levels, points, and character customizations were expected to bring internal motivations such as competence, autonomy, and relatedness [43]. Points and levels that generate behavioral incentives help improve users' skills by prompting them to perform specific actions [11].

6. Design: "Fine-Dusty"

6.1. Gamification features

Figure 2. Interface design of the Gamification features

(a) Narrative or story: The basic story is that the user and character spend a day together. The avatar shares the location, and the user manipulates the character accordingly. The character's condition and environment changes depending on particulate matter conditions. (b) Tasks: Actions that address particulate matter exposure are the basic method. Depending on the level of particulate matter, the character induces counteractions through a speech bubble. When the user clicks on the speech bubble, the character shows an animation appropriate for the action. Information is provided An encyclopedia lists information regarding tasks, which are response activities and prevention methods for particulate and ultraparticulate matter. (c) Avatars: The main character is a white puppy whose hair gets dirty depending on the particulate matter conditions. (d) Character customization: Outfits or furniture that can be

obtained are provided in the form of sprouts. Through sprouts, people can purchase clothes or interior items at a store to decorate characters or the environment. All items are related to responses to and prevention of particulate dust. (e) Customization and personalization: The main background has two types, indoor and outdoor, depending on the user's position. In the interior, it gives a information regarding particulate matter since the outdoor background is partially visible through windows. (f) Points and levels: Sprouts are provided to users as a reward for completing the given tasks.

7. Evaluation

An evaluation was conducted to investigate whether "Fine-Dusty" meets its predefined objectives [34]. Both quantitative and qualitative approaches [14,28] were used for the evaluation phase. To measure the effectiveness of "Fine-Dusty" as a service, the quality model technique was also used [9]. A test was conducted with 35 people in the 20- to 30-year-old age group—20 were women and 15 were men. Most of the participants lived in Republic of Korea; 76.28% of the participants lived in Seoul and 20% in Gyeonggi-do. Also, most of the participants were students (22.85%), employees (20%), designers (14.28%), or nurses, civil servants, businessmen, researchers, or unemployed (5.71%). Regarding educational major of the participants, arts had the highest proportion (34.28%), followed by engineering (22.85%), humanities or social science (20%), or business, economics, and nursing (8.57%).

7.1. Evaluation plan

Table 3. Three different situations assessed

Situation 1	Time	Before leaving home
	Place	House (indoor)
Situation 2	Time	Outdoor activity
	Place	Outdoor
Situation 3	Time	After coming back home
	Place	House(indoor)

7.1.1. Evaluation process. The application is composed of information on the status of, responses to, and prevention of particulate matter. The tasks performed in the user test allowed users to take advantage of all functions. After the task was performed, users evaluated the application through two methods: a survey and an interview. Testing was conducted in three steps: (a) The user conducted a presurvey; (b) the user played a prototype game in trial mode with the task we gave; and (c) after completing the trial, the user completed follow-up surveys and interviews. Testing was done for two consecutive days in June 5th to 10th under the assumption that the concentration rate of the particulate matter was bad. Users performed a task in a given situation through a web address delivered to their mobile device. Therefore, testing was conducted in the form of remote unmoderated user testing[39]. Situations were organized as shown in Table 3. The user performed six experiments—three times a day for two days. Each time the experiment was finished, the user sent a short review of each situation's tasks. Combination of seven types of tests that were suitable in the given situations occurred: (a) check the status of particulate matter, (b) conduct prevention and countermeasures, (c) identify guidelines for particulate matter prevention and response, (d) obtain compensation by completing prevention and response tasks, (e) obtain useful items using compensation, (f) utilize items, and (g) check particulate matter levels and understand how to address them.

7.1.2. Survey method. The survey was conducted twice to measure the amount of change before and after using the application, and it assessed the user's awareness and control of particulate matter and countermeasures. Questionnaires were composed of three categories: (a) verification of the effect of using the particulate matter app, (b) exploration of factors to accommodate particulate matter apps, and (c) evaluation of information design attributes. All questions were measured using a 5-point Likert scale (1 = *not at all*, 5 = *very much*). Each question was modified and reconstructed based on previous research [22,23,24]. Presurvey questions only consisted of verification of the effectiveness of the application, whereas postsurvey questions included exploration of factors that accommodate particulate matter apps and assessment of information design attributes. Detailed description regarding the questionnaires: https://docs.google.com/document/d/1CbR4rQJKDgb4PNXkmiG-vdsDuSgSgXEtpYCIHakZRzA/edit?usp=sharing

7.1.3. Interview method. Postinterview questions were further conducted to supplement each user's experiences that were related to survey questions or difficult to understand by survey questions. The interview was semistructured and divided into four categories: (a) experience using particulate matter apps, which evaluated the experience of using the app and whether it impressed users (through negative experiences and errors during the experiment, we identified improvements to the app design); (b) characteristics of information expression, which detailed questions about characters, overall game design, and task-specific information delivery (this checked whether particulate matter information was well

contained in the game and the flow of the character's information was natural; (c) tendency to accept information, which addressed how the user accepted information related to particulate matter during the game and searched for information afterward; and (d) level of awareness of particulate matter problems, which focused on how changes in the level of recognition occurred after application usage.

7.2. Results

We first provide the results of a *t*-test that determined differences in the effect of the app between presurvey and postsurvey data. Then, mean scores of the factors to accommodate particulate matter apps and assessment of information design attributes were evaluated. Furthermore, interviews were evaluated using qualitative axial and selective coding.

Table 4. Result of *t*-test: effect of the app

		M diff	*df*	*p*
1	Reduction action	-0.4850	32	.021
2	Knowledge of particulate matter	-0.3485	32	.017
3	Empowerment	-1.4242	32	< .001

7.2.1. Results of *t*-test. To validate the statistical significance of differences in participants' scores associated with modality, *t*-tests were conducted. We found a significant difference in degree of reduction action (t = -2.4240, p = .021), knowledge of particulate matter (t = -0.3485, p = .017), and empowerment (t = -6.645, p = .104). Moreover, among variables that showed significant differences, empowerment (μx-μy = -1.424) showed the highest difference between presurvey and postsurvey. Degree of reduction action (μx-μy = -0.485) showed the second-highest difference, followed by knowledge of particulate matter (μx-μy = -0.349).

In the Postinterview, users also reported that their empowerment, degree of reduction action, and knowledge of particulate matter significantly differed after using the app. Users said they felt empowered, confirming that positive motivation arose as they completed tasks and experienced acheivements in the game. This gave them confidence that the results of their response to particulate matter in the real world would also be effective. "Since I'm in the real world suffering from particulate matter, I felt something was getting better after playing game" (P26). Additionally, participants reported the application was effective in increasing the degree of reduction action. "It's a problem that we have to hold on to, and yet I think I should respond actively to it to reduce at least some damage" (P21). Even though the application may have little influence on the view that the problem should be solved by policy and diplomacy, Participants mentioned that it increased certainty that some part of the problem could be changed by individual efforts. Regardless of their existing level of knowledge, all participants mentioned their knowledge of particulate matter also improved compared to before using the application. "Even though I thought I was familiar with particulate matter, there was additional information that I did not know" (P35). This result verifies the research of Kim et al. [20]; an individual's level of knowledge directly influences intent to address or reduce a dust source on an individual level.

Table 5. Means and standard deviations regarding exploration of factors to accommodate particulate matter apps and evaluation of information design attributes

	n	*M*	*SD*
Perceived ease of use	33	4.677	0.475
Emotional	33	4.379	0.635
Specificity	33	4.197	0.637
Potential to personalization	33	4.045	0.774

7.2.2. Result of descriptive statistics. To compare the scores between factors that accommodate particulate matter apps, descriptive statistics were used. Perceived ease of use showed the highest mean score (μ = 4.677, σ = 0.475). It was reflected in most of the interviews. "It was good because the game was simple with easy manipulation" (P18). Users could complete the tasks with ease because the game was simply and straightforwardly designed. Highly evaluated ease of use could be understood as indicative that "Fine-Dusty" might bring external motivations related to utilitarian systems [3, 40].

Regarding descriptive statistics for information design attributes, emotional had the highest mean (μ = 4.379, σ = 0.635), referring to the emotional element of the character. Next came specificity (μ = 4.197, σ = 0.637) and potential of personalization (μ = 4.045, σ = 0.774). This means emotional, specificity, and potential of personalization were evaluated as effectively designed information attributes compared to other attributes in this application, "Fine-Dusty."

The result of the statistics was also shown in the interview result. A participant stated, "The character is so cute, I want to raise it and I want to make it the best dog in the world" (P36), "I'm concerned much more because I'm in charge of an animal, instead of taking care of myself" (P28). Most of the participants said the character was cute and attractive. It also gave participants a sense of unity by incorporating the character's actions with those of the users. This can be understood as reflecting that hedonic intrinsic

motivation increased the emotional benefits by creating a playful experience centered on the entertainment factor [27]. Second, Regarding specificity, participants responded that "specific information was obtained from the encyclopedia feature" (P31). Participants stated that information regarding the task provided by the encyclopedia was specific and proved effective in increasing their knowledge. This result bolsters research that essential risk communication factors, which are complexity, expertise, and certainty, led to individual information acquisition [24]. Last, a high possibility of personalization was observed during the interview. "I felt that the game was well connected to my situation because I have been informed of how to respond to the present situation" (P18). The narrative or story and task during each scenario being based on the user's personal schedule also affected the reality. Furthermore, the respondents stated that the game's environmental designs being connected to that of user's helped them feel the effect of personalization. This result supports the research of Li et al. [29]; For communication of information regarding a response behavior, personalized information should be presented to increase accept psychological acceptance of information [1].

8. Discussion and conclusion

8.1. Discussion

Table 6. Game elements and Information design

	Motivation	Game element	Information Design
1	External	Utility	
2	Internal (Immersion)	Narrative	Emotional Personalization
		Avatar	Emotional
		Personaliza-tion	Personalization
3	Internal (Achievement)	Task Points/Level	Specifity

In this study, we found that immersion-related gamification elements acted as a motivation factor. However, achievement-related gamification elements showed limitations in motivating users. Narrative, avatar, and personalization factors were major elements in the immersion-related gamification features of the "Fine-Dusty" application. First, the avatar evoked immersion of the users during gameplay [35]. Also, this could be understood as an interactive communication method stimulated by the emotional aspect, such that the character's appearance and protection instinct stimulated immersion [10]. However, limitations regarding the avatar were also mentioned. We confirmed that the role of the character that gives quests to users must be accurately defined in risk situation information communication. There was confusion among users regarding the role of passively responding to the actions and the speaker actively delivering response information. Excessive amounts of information forced users to deal with the game passively because it strengthened its indicative nature rather than a protective instinct

Second, narrative and personalization were also evaluated as immersion-related gamification features. Users who recognized narrative scenario was set in a form that corresponded—that the character's environment was connected to their reality—reported that they felt a sense of unity with the character. Also, users who recognized the personalized features of the narrative better realized that the task was an applicable response on a real-time basis. For example, Users who sensitively perceived the personalized narrative especially remembered each of the situation-specific tasks based on each context: outdoors, indoors, and home. There was also positive feedback. The tasks that were provided according to the situation of response and prevention which thereby enables personalized game service. These evaluation findings strengthen previous research that gamification features of personalization and narrative evoke immersion among users [37]. However, we identified the need for easy recognition of virtual environmental interface designs, such as a background user interface that expresses the status of the particulate matter in different colors, to more clearly communicate to users, which would be important factors to enhance personalization.

Third, this research had limitations regarding the application of achievement-related gamification features that encourage internal motivation, specifically gamification features such as competence and achievement [43]. Points, levels, and task settings were identified as elements that should be improved to function as gamification elements. In "Fine-Dusty," information on the adverse effects, causes, and various countermeasures of particulate matter were provided by the tasks. Using the encyclopedia, users could also obtain details about the game task. However, The amount of information and the method of expressing information were too descriptive, some users questioned the inconvenience and identity of the game. Also, the users mentioned that more information should be provided according to the level of the game development for continuous use of the player. The importance of the game level was also shown because the game service is currently at a basic level, and risk and compensation factors should be designed to encourage continuous use of the game.

8.2. Conclusion

In this study, a novel solution to risk communication was explored using gamification attributes. We followed design science research methodology [14,28] and the design process of gamification [34] from analysis to evaluation. Information design factors derived from users were implemented to gamification elements, and remote unmoderated user testing, pre-sruvey, post-survey, post-interview were conducted to assess the possibility of implementation, effect of each game element on user motivation [43], and differences in risk communication.

In conclusion, "Fine-Dusty" stimulated psychological and behavioral outcomes in users. In the case of psychological outcomes, both internal and external motivation was extracted. Utility was comparatively evaluated higher than other attributes and can be understood to stimulate external motivation [4, 40]. Also, in the case of narrative background, avatar, personalization, and customized character, these elements were evaluated to encourag immersion and autonomy among users, which are forms of internal motivation [10]. However, internal motivation elements related to achievement [43], such as tasks, points, and levels, showed limited effects on users. Furthermore, regarding risk communication, a significant difference in degree of reduction action, knowledge of particulate matter, and empowerment was found. Therefore, immersion-related gamification features that were effective for users could be a major attributes that influenced psychological motivation and simultaneously required risk communication features such as specificity, emotional, and personalization elements that were properly implemented in this risk communication game.

However, Since the main focus and purpose of the research was proving the possibility of risk communication gamification, not all elements of the gamification were implemented in detail. Therefore, the lack of game elements compared to an actual game was a major limitation. Subsequent research should focus on the development of achievement-related and social-related gamification features, which enhance the affordance attributes of gamification [43] and the effectiveness of risk communication in an advanced level.

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